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NAVY SCIENCE ASSISTANCE PROGRAM (NSAP) PROJECT SURFP-6-76 HICOM ALERT

A test of the feasibility and effectiveness of a selective-call alarm for improving HICOM network responsiveness

Test and Evaluation, June to November 1976

John H Townsend

17 November 1976

Prepared for

NAVAL SURFACE WEAPONS CENTER
Silver Spring, Maryland

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A selective-call alarm system was implemented for tests over the HICOM network. It was found that this type of system can significantly enhance HICOM responsiveness, and Fleet installation is recommended.

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FOREWORD

The Navy Science Assistance Program (NSAP) was established by the Director of Navy Laboratories in June 1970 to provide quick-reaction response to urgent needs of the Fleet. Under the NSAP, which is administered by the Naval Surface Weapons Center (NSWC), Silver Spring, Maryland, science advisors and representatives are assigned to work directly with Fleet Commanders. These NSAP personnel – all volunteers from Navy laboratories – provide assistance in areas such as command control, communications, electronic and antisubmarine warfare, and air defense. Thus, the entire Navy laboratory community is represented in providing technical expertise to the operating commands.

This project (SURFP-6-76) was initiated by the Commander, Naval Surface Forces, US Pacific Fleet, as an NSAP task to address one of the perceived problems affecting the High Command (HICOM) network responsiveness. The NSAP Director requested a proposal from NELC to conduct a feasibility demonstration of a selective-call alarm. The resultant tasking defined the scope of the project summarized by this document.

OBJECTIVE

The High Command (HICOM) network is a high-priority voice channel between operational commanders and individual units. Because of its high priority, certainty of communications is required; however, a number of factors militate against perfection. Therefore, it is always desirable to improve HICOM responsiveness. The most serious problem in normal HICOM operation is operator inattention; it was felt that some sort of device was needed to alert HICOM operators. This project investigated the impact of a selective calling and alarm system, the feasibility of meeting current needs with existing technology, and the implementation factors to be considered.

RESULTS

1. A selective-call alarm can significantly enhance HICOM responsiveness.

2. Although the project measures of responsiveness are not related directly to normal network operation, the operator inattention problem was virtually eliminated by the call system.

3. Various operator and propagation problems were also analyzed.

4. Information to support the eventual implementation of selective call for HICOM was developed.

RECOMMENDATIONS

1. Expeditiously implement a selective-call alarm system for HICOM consistent with Fleet priorities.

2. Incorporate the features detailed herein.

3. Change the transmission mode for HICOM as soon as practicable; high-frequency propagation problems are extensive.

ADMINISTRATIVE INFORMATION

This document was compiled as part of the Navy Science Assistance Program (NSAP) Project SURFP-6-76, Program Element NIF, Project 0, and Task Area NSWC (NELC S202). It summarizes work performed from June to November 1976 and was approved for publication 17 November 1976.

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The communications personnel of the following commands provided valuable cooperation and comments:

Naval Communications Station, San Diego

USS BAGLEY (FF 1069)

USS BRADLEY (FF 1041)

USS MOBILE (LKA 115)

USS SCHENECTADY (LST 1185)

Additionally, the author expresses appreciation and gratitude for the outstanding contributions of RMC McFadden and RM1 Edwards of NAVCOMMSTA, San Diego, and of RMC Lotz of COMNAVSURFPAC. Their efforts were essential to the successful completion of the project.

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BACKGROUND

The High Command (HICOM) network is a high-frequency voice channel which is used for high-priority communications between operational commanders and individual units. Although the network is seldom used (relative to other communications circuits) for actual traffic, it does carry a number of test communications and exercises to measure effectiveness and to train HICOM operators. Because of the high-priority nature of the network, certainty of communications is a *HICOM requirement. Although a number of* factors militate against perfection, it is always desirable to improve HICOM responsiveness (the measure of the effectiveness of the network).

This project was initiated by the Science Advisor to the Commander, Naval Surface Forces, US Pacific Fleet, as a Navy Science Assistance Program (NSAP) task to address one of the perceived problems affecting HICOM responsiveness. NELC responded to the NSAP Director, Naval Surface Weapons Center, Silver Spring, with a proposal offering three levels of effort. From the three, a moderate-level effort was selected which thoroughly investigated the technical feasibility of a proposed concept, tested it in operation, and developed information from which implementation decisions could be made. The minimum-level effort would have tested only the technical feasibility aspects; the maximum-level effort would have investigated the operational ramifications of the equipment, rather than conducting a cursory examination of its employment, and would have developed data on possible interference problems in a fully deployed system. The maximum effort would have led directly to a service-approval test cycle, but funding limitations dictated the moderate-level effort which would have the effect of deferring some of the acquisition decisions should the feasibility and utility of the proposed system be proven. NELC proceeded to establish liaison with COMNAVSURFPAC and NAVCOMMSTA, San Diego, upon receipt of NSAP tasking. This report describes the resulting project, designated HICOM ALERT, and its results.

HICOM RESPONSIVENESS FACTORS

Three major factors affect the responsiveness of the HICOM network. Two are operator-related and the third is a problem of physics. The operator factors can be described as "cockpit error" and operator inattention. Laws of human error appear to be immutable. The training and responsiveness tests for HICOM are oriented toward maintaining an acceptably responsive network. There are practical limits to what can be done to exclude human error; however, operator inattention has sometimes played a role significantly beyond the combined effects of other factors. Operator inattention was the problem addressed by the HICOM ALERT project. The roles of other factors were also considered to ensure that any interactive effects were taken into account.

The physics problem of propagation at high frequencies is a formidable one. One of the first considerations in investigating the matter of propagation is the location of HICOM in a high-frequency band. Distance requirements preclude the use of higher frequencies which are line-of-sight limited. The low-frequency and very-low-frequency bands are practical for transmitting from shore stations to ships, but the reverse link becomes impractical because ships are too small to have efficient omnidirectional antennas in the low bands. In addition, surface ships do not have a requirement to transmit in the low bands and currently do not have equipments to support such a requirement. Further, HICOM is not of such a nature as to justify a transmitter to be procured and installed strictly to support the operation of the network in a low band.

High-frequency propagation characteristics change geographically with time of day and with season in a relatively predictable pattern; sounder data are continuously improving high-frequency propagation predictions. If HICOM were the only network of concern operating at high frequencies, a frequency set for HICOM could be selected and scheduled for different areas of the world to virtually guarantee coverage. The frequency set for HICOM would also be optimum for other high-frequency networks which are also experiencing the same propagation problems. Therefore, it is not possible to generate a practical frequency plan which would account for all high-frequency propagation effects. Nevertheless, given the special diversity of shore stations and the present frequency-management practices for HICOM, it should be possible to minimize high-frequency propagation problems for any coordinated broadcast.

Prior work at NELC, sponsored by NSAP, examined and recommended solutions for four US Taiwan Defense Command communications problems. These recommendations were contained in a report authored by TL Comport in February 1974. Included in the report were directions for choosing a transmitting site to maximize the chances of a ship receiving a broadcast. One of these methods is for the ship to be monitoring two or more frequencies at the same time. A practical problem is faced in this connection since the ships do not have sufficient receiving and transmitting assets for this purpose. In addition, ship personnel often do not have time to use the predictive tables to determine which frequency is most likely to be the best at a given time. Their predictive efforts are normally reserved for the hard-copy networks such as Fleet Broadcast. Many times, trial and error becomes the most effective method of attacking the propagation problem aboard ship.

Operator errors have a great effect upon HICOM responsiveness. Typical errors include the mispatching of receivers, transmitters, and audio terminals and mistuning of receivers and transmitters. Two factors which affect the operator error rate are training and command attention. The exercises and tests conducted on HICOM play major roles in mobilizing both factors toward minimizing operator errors.

Interviews with communications personnel revealed that operator inattention was a major factor in HICOM nonresponsiveness. Because, even with exercises and tests, HICOM is not a very busy network, ships do not designate an individual as a full-time HICOM operator. Also, noise and atmospherics make HICOM a background noise nuisance on most ships and, as a result, it becomes very easy for ship personnel to miss a call.

The situation is further compounded by the security procedures applied to call-sign assignments. The HICOM call signs are "double alpha" in construction ("alpha romeo" for AR or "sierra echo" for SE, using the phonetic alphabet) and are changed frequently and regularly for each command. Operators easily recognize standard call signs just as an individual can hear his own name called in a noisy room. However, because HICOM call signs are changed frequently, they never can become assimilated by ship personnel. This problem is further compounded for a ship guarding several group and embarked command call signs as well as its own.

Unless the HICOM network is moved to a secure satellite channel or supplanted by a different mode of command control communications, the problems just discussed will remain very real. The broad purpose of HICOM ALERT was to address the feasibility of improving HICOM responsiveness. Operator inattention was the largest variable factor and the one found most susceptible to technical solution.

SYSTEM CONCEPT

The conceptual approach toward overcoming operator inattention was to provide a selective-call alarm system which would react with a distinctive warble tone and a light only on those ships being called. A scheme was needed to produce an electronic call recognizable by detection equipment on each ship. An encoder would have to be installed at the operator position at each shore station and a decoder would be emplaced on each ship. The system would not interfere with normal HICOM operations and a sufficient number of selective calls would be available to service all ships and group command structures afloat. The ship encoder would react to the ship's own call sign and those of any groups or command embarked aboard the ship. Selective-call devices to accomplish these tasks were found to be available commercially in a variety of forms.

It was estimated that nonresponsiveness due to operator inattention could be virtually eliminated if such a selective-call system were to be proven feasible. New chances of operator error could be introduced as encoder or decoder setup errors, but these could be minimized by devising a scheme whereby code sets on the ship would be easy to change or would be changed automatically.

PROJECT APPROACH

GENERAL

For discussion purposes, HICOM ALERT can be seen as comprised of three broad tasks: engineering, test, and analysis-conclusions. The engineering task included searching for, selecting, and procuring an appropriate selective-call alarm system, designing necessary modifications, and installing the equipments aboard test ships and at the Naval Communications Station (NAVCOMMSTA), San Diego. The test task included test planning, execution, and data collection. In this task, close liaison with key contacts at NAVCOMMSTA and COMNAVSURFPAC communications was essential. The analysis-conclusions task began with a requirements analysis and carried through the test-data reduction to the determination of feasible implementation alternatives. All three tasks were conducted concurrently.

TECHNICAL FEATURES

Technical features of the project were derived from the system concept and from discussions between NAVSURFPAC personnel and NELC engineers experienced in high-frequency communications . The desired technical features of the system are listed in table 1. The overall driving factor was that the requirements of the system be compatible with current HICOM network operation which uses single-sideband voice in the high-frequency spectrum.

TABLE 1. SELECTIVE CALL SYSTEM TECHNICAL FEATURES.

Number of possible selective-call codes	3000 (nominal) 1000 (minimum)
False-call probability	1×10^{-3}
Compatibility with telephone-line audio	
*Compatibility with ssb hf voice	
Power source	115 V, 60 Hz, 1ϕ
Encoder only:	
Output	0 dBm into 125 or 600 ohms
Decoder only:	
Input/output on same line	
Input range	−20 to +15 dBm at 600 ohms
Output	+15 dBm into 600 ohms

*Implies detected tone accuracy of 1 Hz.

Selective-call systems operate by transmitting a tone sequence which is recognized by decoder equipment. Propagation effects at high frequencies cause tonal shifts in each sideband and, since the tone-recognition bandpasses must be very narrow to preclude false alarms by tone shifts in voice modulations, a method of tone reference must be used to present a stable, precise tone output to the decoder from the receiver. Two basic methods may be used to establish this reference. One is the use of a diversity mode of transmission and the other is the use of a reference transmitted tone. HICOM operation required the latter approach be used. Another requirement was that the tone sequences be sufficiently great in number to support a fully implemented Navy system. It was estimated that this number might be as high as 3000 (1297 tone sequences are required by the recommended system).

Several additional features were desired for testing different operating characteristics. These included the ability to change codes in the decoders, multiple code alarms, and a visual indicator requiring a manual reset. These features were not needed to prove the feasibility of selective calling but were important in determining the extent and depth of implementation options, operator controls, and the probable costs associated with various specification characteristics.

COMMERCIAL SELECTIVE-CALL EQUIPMENTS

There are no less than 15 manufacturers of selective-call devices. Only a few, however, offer a system compatible with single-sideband voice at high frequencies. Most of the manufacturers of a compatible system had a very limited code capacity. Only a system manufactured by Lorain Electronics combined the high-frequency single-sideband compatibility and the large number of desired codes.

Commercial delivery operations which use vhf-FM radio systems constitute the commercial market for selective-call equipments. A secondary market is that of shipping companies which use high-frequency single-sideband communications on the oceans and Great Lakes. It is for this latter market that Lorain manufactures its equipment. A market survey revealed that the Lorain system is used very successfully by Great Lakes iron-ore carriers and by the Coast Guard and Military Sea Transport Service. No other potential sources for off-the-shelf equipments suitable for HICOM ALERT were identified, but about a half dozen companies are in a position to compete for a Navy system which could result from HICOM ALERT.

Navy ship environments for HICOM equipment are identical with those environments of commercial carriers except that, in the Navy, electromagnetic interference levels (emi) are higher and acoustic noise in the work spaces is greater. Because of this close similarity of environments, it was assumed, with high confidence, that the Lorain equipment would work as reliably in the Navy environments as in the commercial ones.

The Lorain equipment met the apparent HICOM ALERT requirements except for the decoder interface with the HICOM net equipment. Because it could be modified easily, the Lorain equipment was found to be ideal for project purposes. On the basis of the technical capabilities and a thorough market search, the Lorain equipment was selected and procured. This equipment is shown in figure 1.

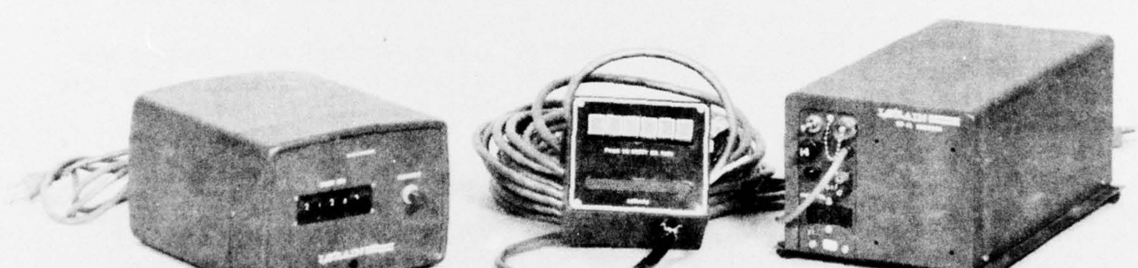

Figure 1. Lorain electronics equipment used in HICOM ALERT (encoder, call indicator, decoder).

MODIFICATIONS FOR TEST

The Lorain encoder required no modifications for installation at NAVCOMMSTA, San Diego. Interface components were added in accordance with installation instructions in the encoder technical manual.

The Lorain decoder is intended for commercial work in the marine band on fixed channel assignments. It incorporates six receiver headends which are fixed-tuned to the channels of interest. The headends are scanned so that each drives a common intermediate frequency and audio module in sequence. The audio output is fed to a tone receiver which translates the received tones into digital pulses and stops the scanning if a valid signal is received. The correct sequence of digital pulses is sensed by the decode module and the alarm is set off. This operation is ideal for commercial applications because the decoder can guard six channels which, in turn, requires only one marine receiver (transceiver) which can be switched to the proper channel when a call is received.

For Navy HICOM use, the Lorain decoder required several modifications because HICOM changes frequency relatively often to minimize adverse propagation effects at high frequencies. In addition, because of the priority traffic passed over HICOM, a receiver is dedicated to the network. Thus, it was determined that the selective-call feature desired for HICOM would operate entirely from the audio output of the receiver.

The decoder modifications eliminated the rf and if circuitry of the Lorain equipment and bypassed the scanning electronics. Input-matching circuitry was added from the 600-ohm balanced audio output to the appropriate input impedance at the audio insertion point. Since there were three possible audio insertion points and the best one could not be selected on the basis of laboratory tests, it was decided that all three points would be tried by using a different insertion point in each of three decoders. A fourth decoder modification version eliminated most of the rf circuitry and the scanning electronics and applied the audio to a modulator controlling an oscillator set at the intermediate frequency (455 kHz). This fourth decoder version was superior in performance to the other three, which used audio frequencies, in that it could accept badly distorted inputs and had a wide dynamic range. The increased complexity of this version, however, almost doubled the cost of the unit and added a maintenance adjustment.

The reason each of the four decoders was modified differently was that audio distortion, input dynamic range, noise, and false-call-rate tolerances were different for each approach used in HICOM ALERT. Although elaborate laboratory tests could measure each parameter, the actual conditions on the HICOM network were not known so no "best" modification could be determined.

A further modification wired the internal audio alarm so that it would be switched to the audio connector when the alarm was actuated; space contacts on the alarm relay were used. This allowed the decoder to be patched in parallel with speakers to the HICOM receiver. When the proper code was detected, the alarm could be heard over all the speakers.

TEST PLAN

For the level of effort tasked by NSAP, five ships were nominated by COMNAVSURFPAC to receive decoders. Each decoder was assigned an individual code which was unique to the ship on which it was installed. The codes were permanently set in consecutive order, for the purposes of the tests, in order to simplify operator tasks at NAVCOMMSTA and aboard ship. The test ships were selected to be representative of the Fleet in size and past responsiveness to HICOM. Because of the large number of test calls, compared to the norm, directed at any one ship, five control ships were selected to be called with the same frequency as the test ships. The control group enabled comparisons to be made with respect to responsiveness of the test ships and of the rest of the Fleet.

The formal test program consisted of laboratory tests, ship-installation tests (in port), demonstration tests at sea in the Southern California Operating Area, technical measurements, and postdemonstration laboratory tests.

The initial laboratory tests measured the system parameters of the commercial units and checked them for proper operation. Additional laboratory tests proved the modifications were functional. The installation tests verified the operation of each installed unit. The demonstrations at sea proved the feasibility of the selective-call concept and measured the responsiveness of the test ships versus that of the remainder of the Fleet. The technical measurements consisted of collecting false-call and error data and various characteristics of high-frequency propagation. These measurements were conducted at prearranged times during the at-sea demonstrations. The postdemonstration laboratory tests were required to resolve differences between the equipments which were tested and the recommended specification characteristics for service equipment.

The demonstration data were gathered from two sources, NAVCOMMSTA logs and an automatic recorder at NELC. The recorder at NELC was established to supplement the normal logs with limited propagation data and to provide redundancy. No ship records, reports, or messages were required.

A test schedule was established which provided for tests of selected test ships and control ships six times in each 24-hour period. The tests were conducted at random but were constrained to provide data for daily variations in high-frequency propagation.

Because of a late schedule change, one of the five ships nominated to receive equipment was not available at the time of installation. The progress of the tests at the time this ship did become available indicated that the fifth decoder could best be utilized in the laboratory to resolve questions as they arose. Since plenty of data were available from the four test ships, the installation of the fifth decoder was dropped from the schedule.

DATA ANALYSIS

RESPONSIVENESS IMPROVEMENT

Over 400 call attempts were made during the demonstration-test phase. Each attempt was analyzed for propagation conditions and approximate ship location using standard high-frequency propagation predictions and ship operating assignments (or track data from ships participating in the exercise). Instances of known equipment failure and nonresponsiveness due to exercise constraints (such as Emission Control (EMCON) conditions) were eliminated. Questionable attempts at response were left in since other factors could cause the observed effects.

The ships equipped with the selective-call alarm immediately demonstrated a 37-percent raw response rate (no compensation for propagation). This figure improved to 47 percent as the testing progressed. An additional response of 2 percent occurred when the alarm failed to function but the ship answered as required. A conservative compensation for propagation (done on a call-by-call basis using standard techniques and ship position) corrected the initial response rate to 77 percent and the final response rate to 97 percent. The final rate was reached in 3 days of testing and remained relatively constant (see figure 2).

The control ships initially exhibited a raw response rate of 10 percent which improved in a linear manner to a final raw rate of 33 percent over a 6-day period. As was

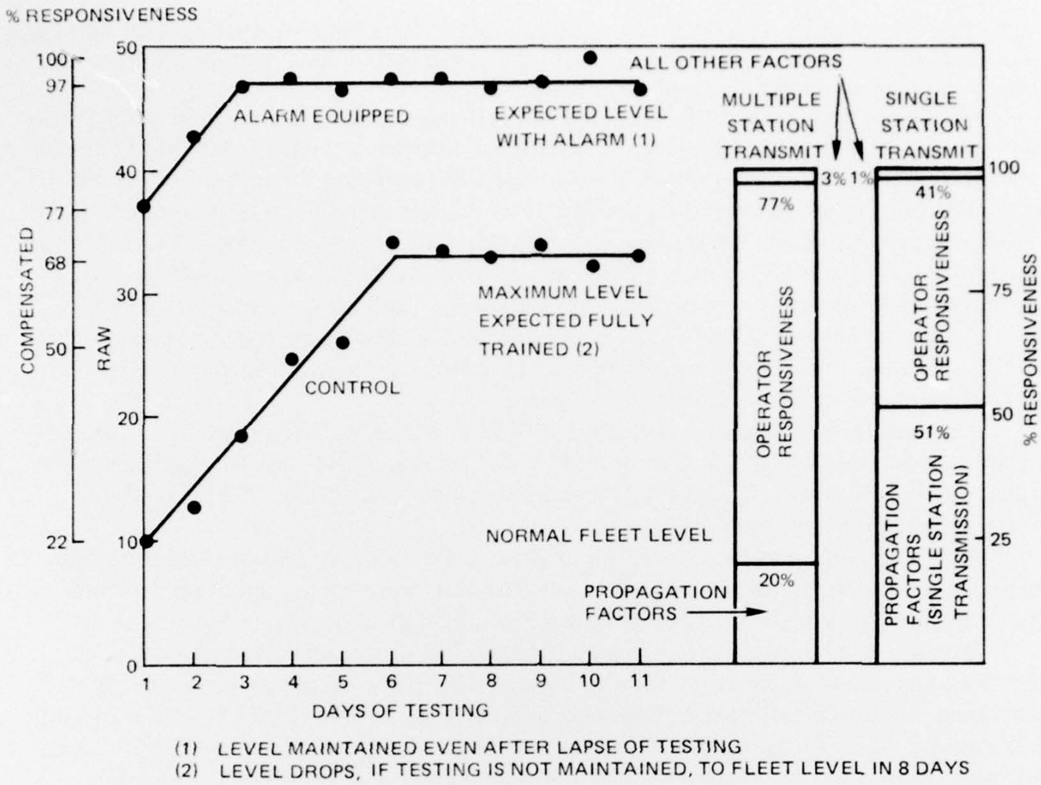

Figure 2. Responsiveness results.

the case with the equipped ships, the final rate remained relatively constant once it was reached. The compensated response rates for the control ships were 22 percent, initial, and 68 percent, final. Notably, the compensation factor was nearly the same for both test groups, indicating the large influence high-frequency propagation has on HICOM responsiveness. About 52 percent of all valid calls initiated received no response because of propagation difficulties.

The "learning curve" feature was expected because of the low call rate on HICOM. When the call rate was increased markedly during the test program, the operator attention to the network also increased. The "learning curve" for the test ships consisted primarily of setting the proper levels and familiarizing the operators with equipment characteristics. The test ships reached their final response level rapidly and held it even when no tests were conducted during 2 intervening weeks. On the other hand, the control ships took longer to reach a maximum response and their response dropped when they were not tested for a period in excess of 8 days. Furthermore, no control ship had a perfect response rate whereas two test ships (50%) did, on occasion, reach a responsiveness level of 100 percent. In normal Fleet operations, the selective-call system should improve HICOM responsiveness by at least a factor of four.

Because of the manner in which testing was conducted, the figures presented in this report cannot be construed to reflect directly actual Fleet responsiveness levels. The project measured the response to each call attempt and the attempts were made by a single transmitting station. Fleet responsiveness levels are based upon multiple calls from several transmitting stations and require a single response within a specified time to any one call attempt. For this reason, the rates measured during HICOM ALERT will always be lower than Fleet measured rates. The technique used by HICOM ALERT was necessary to discern the full impact of each response problem. The conclusions drawn from these data may be properly applied to Fleet experience.

OPERATOR DATA

Operators aboard the test ships exhibited a learning curve of 3 days which was attributed to familiarization and setting of levels. Because of the simple nature of the decoding equipment, familiarization should not have required more than 1 day. This observation, however, cannot be discerned in the data. Level-setting difficulties, on the other hand, underline a prevalent problem which must be addressed in any study of HICOM responsiveness.

The HICOM ALERT decoder was equipped with an audio alarm which was preset to be at least 10 to 12 dB above the standard audio level presented to the speakers. This level was intended to be significantly greater than normal network traffic so that it could be heard even if the operator turned down the speaker to reduce noise. During the tests, it was noted that the actual output levels of the system were set at or near maximum instead of 0 dB (plus line-loss compensation of 1 or 2 dB). As a result, the ALERT alarm was about 3 dB below the normal net level at the speaker instead of being at least 10 dB above. Often the alarm could not be heard in the CIC where the network guard was maintained at sea. When the levels were corrected, the equipment functioned without difficulty.

The level problem results from improperly performed equipment checks made as part of the Planned Maintenance System (PMS). Normally, the level problem is not critical, but it is symptomatic of a more serious widespread problem (affecting at least 40 percent of the ships surveyed). In the opinion of project personnel, the ships do not have sufficiently experienced personnel to support properly the total maintenance load at the level dictated by the equipment designs. As a consequence, normally unimportant PMS checks, such as level setting, receive cursory attention. There is also the danger that the problem extends to other more critical adjustments called for under PMS. The level-setting problem must be dealt with in the acquisition and implementation of a selective-call system by providing at least two independent audio alarms (for CIC and RADIO).

A second observation relative to the operation of a selective-call system on HICOM concerns the manner in which codes are selected. The encoder on the test system employed five 10-position switches to select the codes and the decoder operated with an essentially permanent code. In service operations on HICOM, the codes would have to change daily with the change in call signs. Operators and project personnel agree that a reasonable solution would be to permanently associate the call signs and codes. At present, there are 36 by 36 call signs (plus some fixed call signs) and they consist of two digits from a field consisting of the alphabet and 10 numerals. It is proposed that each decoder and encoder be provided with two 36-position thumbwheels for selecting the code by setting the proper call sign. A separate encode and decode would be provided for a fixed group call. This arrangement will minimize operator errors.

One of the features of the alarm equipment was an automatic alarm test when power was applied to the decoder. Under normal circumstances, this is a convenient test feature. In other circumstances, such as during training, ships frequently experience power interruptions which cause the alarm to sound. Even during normal steaming, power interruptions are sufficiently frequent to be annoying. During the tests, there were instances when the two-tone sequence was detected but no voice was heard. The self-test feature, as implemented in the ALERT test, created an ambiguity in the alarm-no-voice situation. On several occasions, test ships received alarms without voice calls and interpreted them as power-line transients when, in fact, a call had been initiated. Had the ambiguity not been present, the ship would have initiated call-back procedures.

The audio alarm made use of a warbled tone and was very effective in attracting attention. The tone was aptly described as a "sick canary" and resembled some types of high-frequency transmissions. The time constants of the warbling tone in future systems should be altered slightly to eliminate any chance of confusion.

TECHNICAL PARAMETER ANALYSIS

No distinction could be made during the tests in the performance of three of the four modified decoders. The fourth decoder, as modified, had the greatest sensitivity but the smallest noise tolerance. This version was virtually disabled by the high-frequency net noise and had to be replaced. The remaining decoders all exhibited proper input dynamic range and noise tolerance. Variations in tolerance of audio distortion, predicted earlier, were completely masked by the characteristics of the tuning-fork tone filters. These filters were found to be susceptible to odd-order harmonic distortion which is very common in Navy communications networks because of the several audio compressors in the transmit-receive path used for smoothing signal-level variations. Laboratory tests successfully duplicated this odd-harmonic distortion and demonstrated a fix which uses active filters in place of the tuning-fork type. The required tolerance of harmonic distortion is estimated to be 18 percent.

The estimated false-alarm rate (FAR) is 1.8 percent. FAR turned out to be virtually independent of modification differences which affected the ability of the decoders to distinguish between interfering tones. The predominant factor affecting FAR was found to be network noise. This noise is capable of causing an apparent dropout of a tone, under weak-signal conditions, which causes the decoder to count the tone twice and to falsely trigger the alarm. More serious is the alarm failure rate (AFR) of 2 percent and it is caused by the same mechanism which results in the FAR but is a failure to trigger the proper decoder. In practice, the FAR is much less serious because the falsely alarmed decoder will probably not be within radio range of the transmitter and the false alarm is nondamaging operationally. The AFR becomes negligible if an operational procedure is used in which the call is repeated if no answer is heard or if there must be a change in tones to advance the decoder count. The tests indicate that the latter approach is preferred because it eliminates a possible source of operator error and because it improves the resistance of the system to certain kinds of jamming and interference.

A number of time constants in the HICOM net affect the sequence of the transmitted tones. During the test, a 1-second tone followed by four tones each 1/6 second in length triggered the alarm equipment. The time constants were such that the shorter tones were lost sporadically. The problem can apparently be solved by extending the length of the shorter tones to 1/2 second. Depending upon the code-recognition scheme used in the decoder, the first tone also may have to be extended.

SYSTEM IMPLEMENTATION

EQUIPMENT ACQUISITION AND DESIGN

No equipment currently exists which appears to meet the requirements of the Navy's HICOM network. However, these requirements can well be met within the established state-of-the-art, and the quantities of equipment to be procured are of interest to commercial suppliers. Since there are numerous prospective suppliers, a competitive procurement appears most promising. The pertinent technical features to be incorporated in this new equipment are summarized in table 2. If an acquisition is pursued which is based upon a single contract for preproduction and production (contingent upon satisfactory testing and service approval) and with appropriate test and warranty clauses invoked, the expected costs should track with table 3. The recent development of dual-tone oscillators comprised of an inexpensive integrated circuit could reduce the cost of an encoder to as little as $300.

INSTALLATIONS

The encoders should be sufficiently small so as not to present any installation problem. The distortion and timing specifications should allow the unit to be plugged in and wired to the output lines at the operator's console. Two outputs should be provided for driving the primary and secondary channels independently. One encoder will be required for each command operator and communications station.

The decoders should be installed in CIC (figure 3) where the HICOM guard is maintained at sea. A speaker and a remote unit should also be installed in CIC, and cable runs for a second remote unit and the input/output line (to be wired into an audio patch-panel) will be required in RADIO. Installation costs in table 3 assume a nominal cable run of 200 feet between CIC and RADIO.

SCOPE

Several implementation scopes may be considered. These range from outfitting major combatants only to outfitting all ships normally required to guard HICOM. Another option is to provide both decoders and encoders to ships or to install decoders only.

An alternative implementation involves broadcasting the alarm itself at a significantly higher level than normal traffic. This would require only tone oscillators at the transmitting sites and would avoid the considerable expense of decoders and more sophisticated encoders as well as the installation costs aboard ship. The HICOM ALERT data show that ships will respond to this type of alarm at a rate similar to the best attainable through intensive training. This rate is well below that attainable with the selective-call system but is a very significant improvement over present methods.

This approach requires very judicious use such as restricted to priority traffic only since overuse will rapidly deteriorate responsiveness. Because of its great potential for abuse and the increased opportunity for making enemy countermeasures more effective, this alternative is not recommended by this study. Nevertheless, this method must be weighed with other factors in choosing an approach for the solution of HICOM responsiveness problems.

TABLE 2.
PROPOSED SELECTIVE-CALL SYSTEM TECHNICAL FEATURES.

Selective-call codes possible	1296 codes selected by two 36-digit switches plus 1 fixed code
*Call failure probability	1×10^{-3}
Compatible with telephone line audio and Navy hf transmission systems	a. tolerance of 20% harmonic distortion b. 0.5-second minimum tone duration
*Compatible with ssb hf voice	Two-tone code digits with tone-difference detection
Power source	115 Vac, 60 Hz, 1Ø per MIL-E-16400
*False call probability	1×10^{-2}
*implies detected tone accuracy of 2 Hz	
ENCODER ONLY	
Output: 2 output lines	0 dBm into 125 or 600 ohms
Able to encode all possible codes with separate encoding switches for the switch-selectable codes and the fixed code	
Optional transmitter key line	
MTBF	15 000 hours
DECODER ONLY	
Input/output on same line	
Input range	−20 to +15 dBm at 600 ohms
Output	+15 dBm into 600 ohms
Provision for 2 remote call indicators with visual indicators which may be reset from either remote and with an audio alarm output of 1 watt (min) up to 4 watts into 8 ohms. Remote units may be up to 600 feet away.	
Alarm test function	
Able to decode 2 codes: 1 switch-selected and 1 fixed	
MTBF	10 000 hours (min)
ENVIRONMENTAL	
1. Temperature	0-50°C
2. Humidity	95% at 30°C; 65% at 50°C
3. Vibration (decoder only)	0.7 g (6.865 m/s^2) 10 Hz to 60 Hz

TABLE 3.
HICOM SELECTIVE-CALL IMPLEMENTATION COSTS.

Development	$135000	nonrecurring
Tests and implementation administrative costs	75000	nonrecurring
Encoder acquisition	1350	per unit*
Decoder acquisition	1450	per unit**
Encoder installation	500	per site
Decoder installation	9500	per ship***

* for 40 units; adjust along 85% learning curve. Newer technologies may significantly reduce this cost but increase development costs slightly.

** for 300 units; adjust along 85% learning curve.

*** assumes two 200-foot cable runs from CIC to RADIO; this figure could vary significantly from class to class. Also, cost might be reduced 40% by combining two cables into one and splitting them at a junction box in RADIO. Costs assume shipyard installation vice ship's force installation, the latter probably practical and much less expensive. For example, a FF 1052 Class installation should be under $2000 including an allowance for tender assistance.

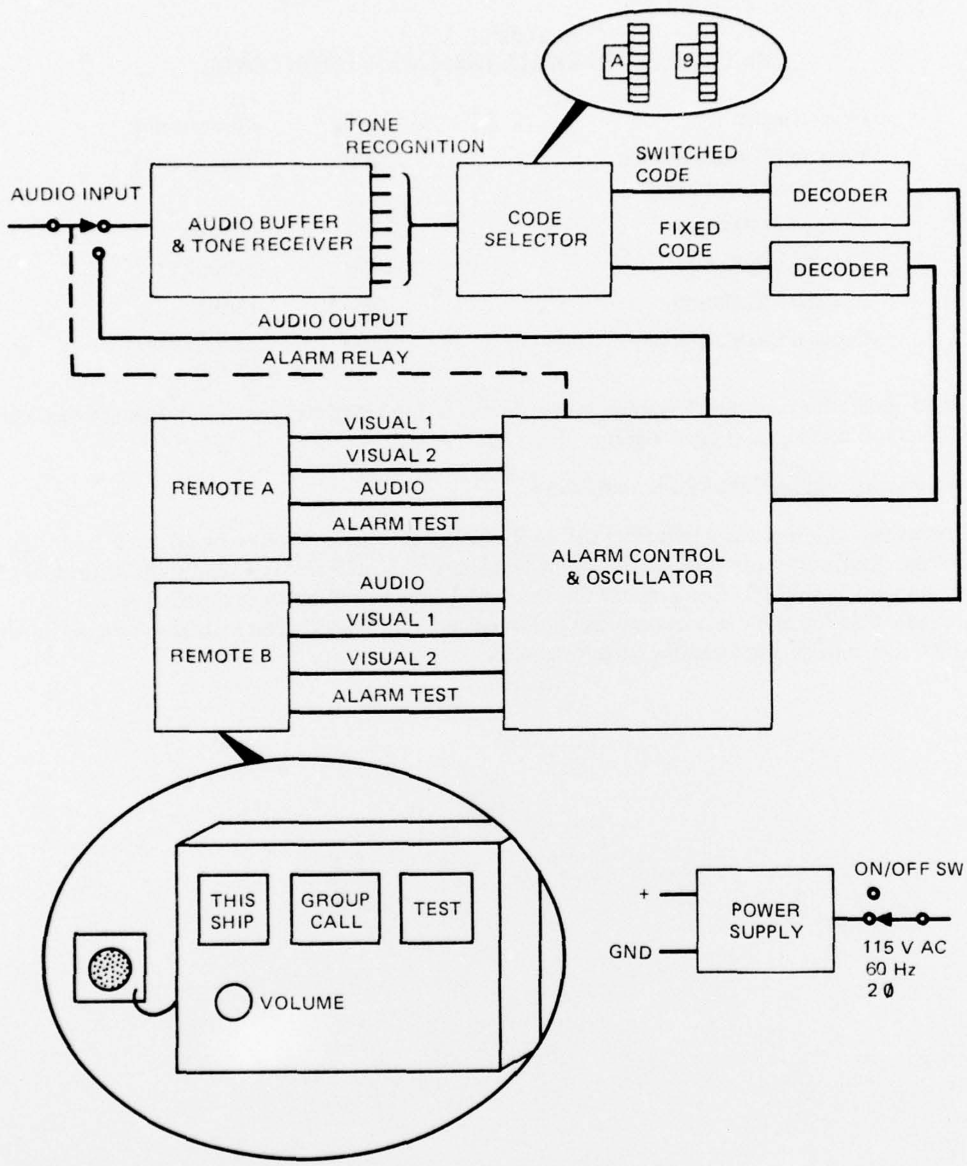

Figure 3. Decoder block diagram.

RECOMMENDATIONS

IMPLEMENTATION

The HICOM ALERT demonstrated conclusively that a selective-call alarm system can significantly enhance the responsiveness of the HICOM network. The results of the study must be considered to be even more significant in Fleet operations than under test conditions. This is because, in Fleet operations, calls from multiple stations will reduce the impact of high frequency hf propagation on responsiveness. The potential value of the system considered in the study is in the high response rate which can be attained with existing training levels. A higher level of training was shown by the tests to improve response rates but this level of training is probably impractical. Furthermore, the response rate, when the selective-call system is used, will probably be higher than the best attainable with intensive training.

The decision to implement selective call for HICOM must consider the current levels of responsiveness, the costs of the system, the practical schedules for implementation versus the availability of alternate paths (satellite), and the importance of the HICOM network. Interviews with Fleet personnel lead to a strong recommendation for implementation including the installation of decoder equipments on all ships.

RESPONSIVENESS PROBLEMS

High-frequency propagation is the primary factor affecting HICOM responsiveness if single-station transmissions are considered. Operator responsiveness is the primary factor if good operational practices are followed, and this factor can be virtually eliminated through the use of a selective-call system. Propagation at high frequencies is a problem which can be solved only to a degree depending upon the location of the ship, the time of day, the time of year, and other factors. High-frequency communications do not provide 100-percent world coverage 100 percent of the time. Even the most optimistic estimates of high-frequency propagation can be less than satisfactory. The propagation problem can be solved only if another mode of transmission is used. Such a new mode is recommended. The proposed selective-call system will be useful even if a new mode is eventually used.

Operator error was cited previously as the third most prevalent problem factor. This is likely to be a problem found sporadically only on individual ships. In fact, all problem factors other than the primary two account for less than 3 percent of the total responsiveness impairment. With a selective-call system, improvements in responsiveness may be obtained by initiating a group call at predetermined times followed by a test announcement. Corrective action could be initiated by ships which did not receive the test call on schedule. This procedure is highly recommended if the proposed system is implemented.

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